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Chemical Control of

Brush Regrowth on Fuel-Breaks

By T. R. Plumb , J. R. Bentley, and V. E. White

FOREWORD

The Fuel-Break Program is conducted cooperatively by the California Division of Forestry, the Los Angeles County Fire Department, and the U.S. Forest Service.

CHEMICAL CONTROL OF BRUSH REGROWTH ON FUEL-BREAKS

By

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Without effective, economic techniques to control regrowth of brush, permanent modification of large areas of chaparral to a stable cover of low fuel volume is virtually impossible. The aggressive reestablishment of most brush species after top removal will soon cancel out any value of an initial clearing operation (3, 14). In 2 years, regrowth may attain a height of several feet (fig. 1). Grass or other cover being established for soil protection is rapidly crowded out (12, 18). Practically all of the brush plants--except those left for esthetic purposes--must be eliminated. If they are not, reclearing is necessary every 2 to 5 years.

The difficulty of controlling brush regrowth is well known to anyone engaged in type-conversion work, hazard reduction, or fuel-break construction. Removal by hand or machine is inadequate to maintain satisfactory control, even on narrow firebreaks (9), let alone the usual fuel-break areas.

In recent years herbicides have become an important tool in the control of undesirable brush and tree regrowth. This report describes the use of herbicides to control brush sprouts and seedlings on fuel-breaks in southern California. Included are: (1) a general description of chemical control techniques; (2) a summary of current spray recommendations for specific plant control problems; and (3) an appendix containing useful tables.

SCOPE AND PURPOSE OF CHEMICAL BRUSH CONTROL

Using chemicals to control unwanted vegetation is not a new idea in southern California (14). Many of the early herbicides were tested almost 30 years ago on firebreaks. But they did not gain widespread use. Many of them are hazardous to use, some ignited spontaneously (6), and all required a

Figure 1.--These large sprouts illustrate the vigorous regrowth that can be produced by some chaparral plants within 2 years after top removal.
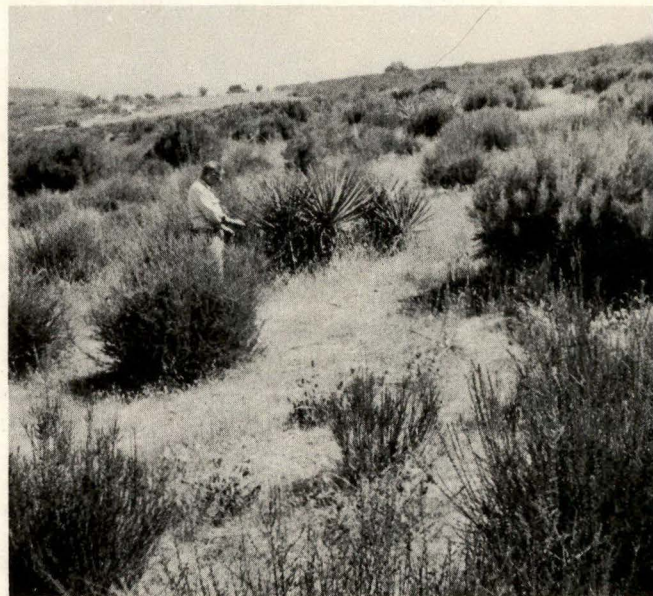
considerable amount of toxicant material per acre. They had little or no selective action and could affect all plants in the treated area.

The big expansion in use of herbicides in wildland management came with the development of 2,4-D and 2,4,5-T in the early 1940's ($\underline{1}$). These easy-to-use chemicals were effective in small quantities (less than 2 pounds of actual herbicide per acre in some control work) and they were selective in their action on certain types of plants. Herbicides are now recommended for most brush control work.

WHY USE CHEMICAL CONTROL?

Herbicides have become popular for a number of reasons.

1. Chemical control costs less because it uses manpower more efficiently and takes less time. One man can hand-spray $\frac{1}{4}$ to 1 acre of moderate regrowth (i.e. 1,500 to 2,500 plants) in one day. Open stands may require considerably less time. A helicopter will spray 50 or more acres in an hour when supported by a 3- to 5-man crew. In contrast, cutting regrowth by hand may take 10 to 25 man-days per acre. On some projects, recutting operations may utilize all available manpower in maintaining limited areas already cleared. New fuel-break construction will progress slowly or not at all.

Costs vary among the methods used and with type of brush. For example, satisfactory control of some plant species, such as chamise (<u>Adenostoma</u> <u>fasciculatum</u>), can be obtained with low-volume broadcast applications of 2,4-D. Total cost may be as low as $10 per acre. Other, more resistant species, such as scrub oak (<u>Quercus</u> <u>dumosa</u>), usually require more intensive hand-spray treatment for complete kill. Control costs may total $80 or more per acre over a 3-to 4-year period. But the cost of other control methods is even greater in this type of cover. Cutting by hand may run as high as $500 per acre.

2. Chemical control does not disturb the soil or destroy grass cover ($\underline{5}$). In contrast, mechanical reclearing increases the erosion potential because of the associated soil disturbance.

3. Chemical control should reduce the periodic maintenance required. Adequate control of the original brush plants usually takes from 2 to 4 years of annual chemical treatment, depending on the brush species dealt with and the method of chemical application. Hand cutting may have to go on indefinitely since this type of work does not necessarily kill the plants. A few of the original plants always seem to survive hand grubbing and mechanical clearing, and reclearing may be required year after year with complete control never being obtained.

WHERE TO USE CHEMICAL CONTROL

Herbicides can be used on practically any recently cleared brush area, including fuel-breaks, range conversion areas, roadsides, and recreation and residential areas. "Recently" means that the clearing is done and the regrowth is less than 3 years old. On areas burned by wildfire, spraying can begin before snag removal is complete.

WHEN TO USE CHEMICAL CONTROL

Timing of the control operation will depend on the method of application used. Foliage sprays should be applied to brush regrowth during the active part of the plant's growing season before the new leaves harden (16). Generally, spraying should be done in the first or second season after clearing. If it is delayed longer, the older plants, generally considered harder to kill (14), may be too large for effective spray coverage. Maximum height should be about 2 to 2½ feet. Larger plants are not only more difficult to spray thoroughly, but also require a greater amount of chemical, take more time to treat, and may even be a fire problem when dead. Plant size will vary throughout an area, but when most are above the maximum height the area should be recleared, and chemical control should be used on subsequent regrowth.

METHODS OF APPLICATION

Herbicides can be applied to the foliage, to the bark, to the cambium through cuts in the bark, to the stump, or to the roots through the soil. Application methods usable on fuel-breaks include:

Foliage sprays, either broadcast over a large area or
applied selectively to individual plants.

Soil treatment.

Cut-stump treatment.

The land manager may need to use one method or a combination of methods. Consequently, each job should be sized up individually to determine the best approach. As a minimum, consider plant species, size of regrowth, time of year, accessibility, and treatment cost.

Plant species.--Plants differ considerably in susceptibility to each method of chemical treatment. For our purposes, however, they can be separated into two broad groups--sensitive species and resistant species. The first group includes chamise, sage, and sagebrush. Most other chaparral plants fall in the second group. A few of the more notably resistant are scrub oak, laurel sumac, toyon, mountain mahogany, and eastwood manzanita. A more complete list is given in table 1 (appendix). Plants in the hard-to-kill or resistant group usually require two to three repeated chemical applications. But there is some variation in the resistance of individuals in each species. Occasionally a few of these tough plants may be killed with one treatment.

Size of plant.--If the regrowth is too large, a light foliage treatment may not penetrate far enough into the crown of sprouts for effective coverage. A more intensive, and consequently more expensive, method will be necessary to get full value from the control operation. The approximate size for best treatment is shown in figure 2. If the plants are too big, reclearing may be necessary. Sprouts may also be too small for effective treatment. If some are still emerging at the time of spraying, a poor kill may be obtained (12). Chamise sprouts should be at least 8 inches tall and scrub oak about a foot. By the time these lengths are reached, most of the sprouts and brush seedlings should have emerged (12).

Density of crown.--The number and spacing of sprouts in an individual plant also affect the penetration of spray material to the lower leaves and stems. An open crown, which favors penetration, may consist of a few scattered sprouts with the root crown and lower stems readily visible. In contrast, a dense crown, especially one that has been browsed by animals, is almost an impenetrable mass of leaves and stems. Although translocation is one of the regularly cited characteristics of 2,4-D, in actual practice, extensive translocation of herbicide to the lower stems and root crowns often has not been obtained (1, 12). Dense crowns require higher spray volumes for complete coverage.

Time of year.--Some control methods are effective only during a limited time of year. Broadcast spraying, for example, generally has given good control only in the spring (14). Timing does not seem to be as critical when plants are sprayed individually although this method should preferably be scheduled for the spring. Present results of individual treatment indicate that good control may be obtained at any season.

Accessibility.--Steep, inaccessible terrain or areas poorly cleared of brush or snags preclude the use of some methods of application, such as broadcast spraying by tractor, and even some types of individual plant spraying. Power or telephone lines or tall trees may make aerial spraying unsafe or impractical. The hazard of chemical drift to adjacent, desirable vegetation also might be considered a factor limiting accessibility. The use of special, viscous spray emulsions which have less drift may be necessary if aerial application is used; but there are some areas where no type of broadcast spraying is safe.

Cost.--If more than one method can be used, cost will certainly influence the final selection of method. But the cost of an herbicide treatment is extremely variable and is dependent on several factors besides those mentioned above. Fixed costs may limit the use of certain methods on small areas. For example, the cost of transporting equipment may prohibit tractor or helicopter spraying. Individual plant spraying, though basically more expensive, may actually cost considerably less per acre than broadcast spraying in small areas. Availability of water and travel distance to the area must also be considered.
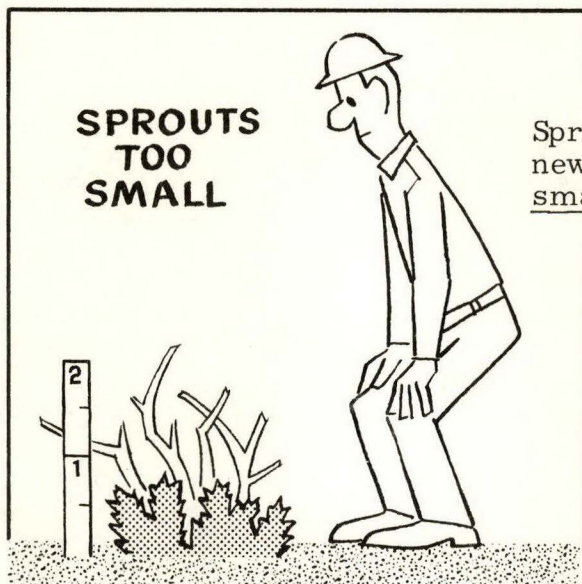
SPROUTS TOO SMALL

Sprouts less than 8 inches tall and new sprouts just emerging are too small for effective spraying.

Sprouts 1 to 2 feet tall are just about the right size for spraying—most sprouts have usually emerged by this time.

SPROUTS JUST RIGHT
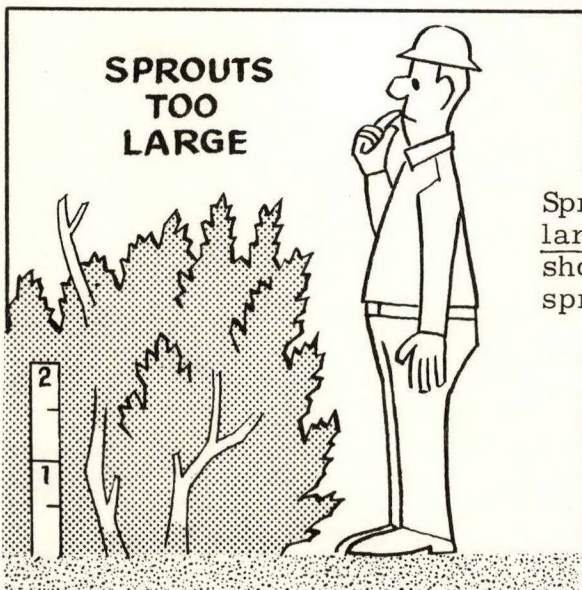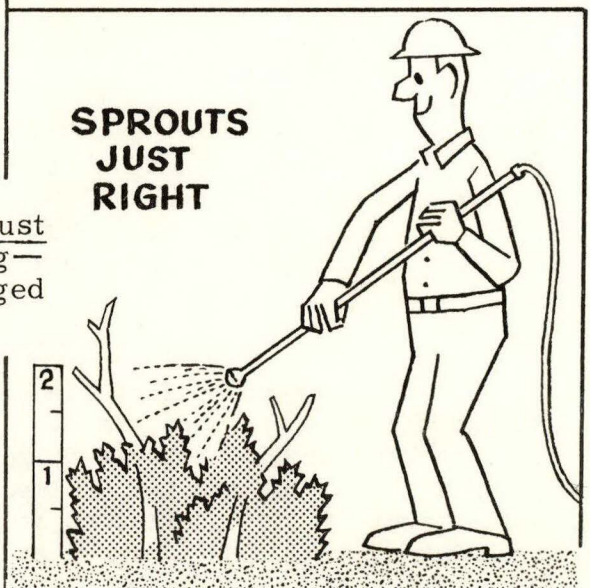
SPROUTS TOO LARGE

Sprouts over 3 feet tall are too large for effective spraying. They should be cut and the resprouts sprayed.

Figure 2.--Sprout height determines spray time.

FOLIAGE APPLICATION

In a foliage application, the leaves and stems are sprayed with a light to heavy dose of herbicide. This is practically the only type of chemical application that has been used to control brush regrowth in southern California.

Low volatile esters (l.v.e.) of 2,4-D and 2,4,5-T are considered to be the most effective herbicides available today for brush regrowth (13). Two such esters are the butoxy ethanol and propylene glycol butyl ether esters. The acid and amine forms of 2,4-D and 2,4,5-T are not recommended for foliage application, and the use of high volatile esters, including butyl and isopropyl, is strictly controlled by the Agricultural Code. Other herbicides suitable for foliage sprays, such as Ammate (ammonium sulfamate) and Amitrol (Amino triazole), seem to have limited application to fuel-break work.

The ester formulations--diluted in a carrier, usually water containing 1 to 5 percent diesel oil--are extremely toxic to broadleaved plants. Spray mixtures containing as little as 1 pound acid equivalent (a.e.)[1] of chemical in 25 gallons of water (approximately 5,000 ppm of active chemical) are generally recommended for hand spraying. Even at this dilution, extreme care must be maintained in order that spray drift does not injure nearby desirable vegetation.

Broadcast Spraying

A broadcast application sprays a low volume of fairly concentrated herbicide--2 to 6 pounds a.e. of active herbicide--uniformly over the area to be treated. Volumes normally range from 5 to 20 gallons per acre. Broadcast spraying has become important in recent years because of the development of low volatile chemical formulations, better application techniques, and improved spray equipment. Most foliage applications have been of the broadcast type.

Where used.--In general, plant species, type of growth, number of plants, or accessibility may determine whether a broadcast spraying is feasible. It should be used to:

a. give complete root kill of sensitive species such as chamise, sage, and sagebrush. Two treatments in successive growing seasons may be required.

b. kill new seedlings of most species. The chemical must be applied at the proper time--that is, during the first or second growing season.

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[1] 'Pounds of acid equivalent' is the usual way that chemical concentration is rated. In this report 1 gallon of undiluted chemical is considered to contain 4 pounds a.e. of active herbicide.

c. retard the growth of resistant species. Usually
    most foliage and succulent stems of resistant
    species, such as scrub oak, will be killed. A few
    plants will be completely killed, but most will
    resprout.

d. accomplish initial treatment if more than 200 to
    300 brush plants per acre are present.

When used.--Timing is important for maximum results from broadcast
spraying. As a general recommendation for one-year-old plants, spraying
should take place during the latter part of the first growing season and
before the leaves harden. The best time will differ from year to year,
depending on growing conditions. When conditions are good, spraying
should begin in early May or possibly late April. When rainfall and
temperature are below normal, late May and early June are better (19).
Plants older than one year probably should be sprayed 3 to 4 weeks
earlier.

Spray operations should begin as soon as plant conditions seem
favorable. Otherwise adverse weather, such as high wind or poor visi-
bility, could delay operations beyond the most favorable time to spray.

Spraying also should begin as early in the morning as possible,
usually at daylight. Wind movement is normally the least at this time.
As air temperatures rise, so does wind velocity. Therefore, aerial
spraying may be restricted to 1 or 2 hours of flying time a day, and it
can rarely be done after 11:00 or 11:30 a.m. Another reason for early
morning spraying is the indication that better control is obtained when
the air is cool and humidity is high (4, 14).

Herbicide can be broadcast from the ground with a tractor-mounted
spray boom, mist blower, or hand-carried boom, or from the air, usually
with a helicopter.

Tractor-Mounted Boom

Most of the early brush control work with 2,4-D was done with a
tractor-mounted spray boom. Generally these units were small and limited
in their operations. A ground unit was developed in 1958 for the rugged
terrain frequently found on fuel-break sites. It consists of a D-7 trac-
tor with a 300-gallon tank-boom assembly replacing the dozer blade (fig.
3). Under favorable ground conditions, this outfit will spray 5 to 6
acres per hour. Production decreases on rough, rocky terrain, on slopes
exceeding 40 percent gradient, and on areas poorly cleared of brush.
Slopes greater than 55 percent are considered too steep for safe opera-
tion. Smaller, more economical units can be used on the most favorable
sites (fig. 4).

Recommendations for chemical rate and volume of spray per acre
have been about the same for the past 3 or 4 years. The standard treatment
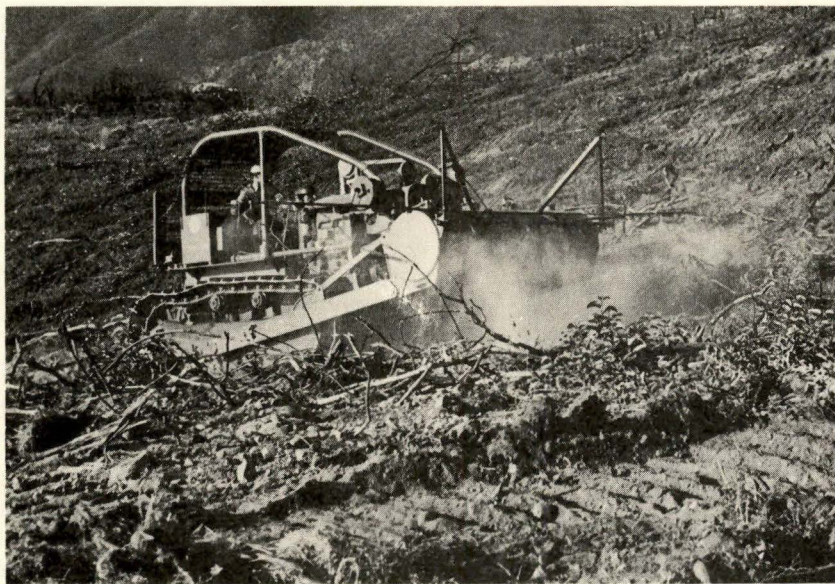
Figure 3.--This broadcast spray equipment was
designed for the rugged terrain frequently
found in fuel-break work. It consists of a
D-7 tractor, 300-gallon spray tank, pump, and
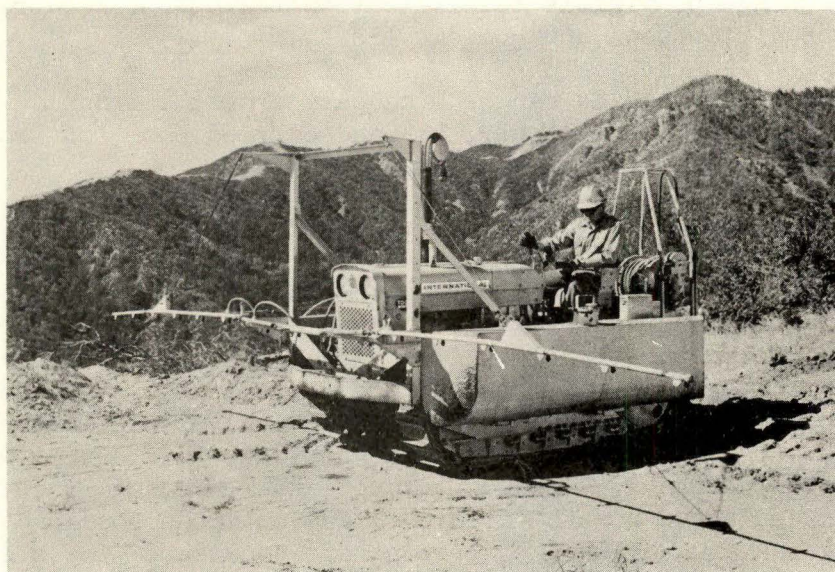25-foot boom.

Figure 4.--Small spray units like this TD-340
are well adapted to areas of moderate slope
and smooth terrain. This unit has two 85-gallon,
saddle-mounted tanks and a 25-foot boom.

consists of 4 pounds a.e. of chemical (1 gal.), 1 gallon of diesel oil, and 18 gallons of water--a total of 20 gallons per acre. Higher chemical rates have not shown an appreciable increase in plant kill and are not recommended. Experience has also shown that a volume of 20 g.p.a. is best on large, dense plants and that lower volumes do not penetrate the crowns far enough for satisfactory kill. However, if the plants are small and have open crowns, a volume of 10 g.p.a. may be adequate.

Straight 2,4-D is used on chamise and other easy-to-kill species. A 50-50 mixture of 2,4-D and 2,4,5-T is considered best for mixed chaparral (13, 19).

Broadcast spraying by tractor has been a reliable way to obtain good uniform plant coverage, and operations are not seriously curtailed by adverse weather conditions. To minimize drift, spraying should always stop when the wind speed reaches 10 m.p.h. In some operations, depending on the drift hazard, lower maximum wind speeds may be necessary.

Twelve dollars per acre is the approximate cost of tractor spraying with a D-7 tractor applying 4 pounds a.e. of 2,4-D in 20 gallons of emulsion per acre. This assumes treatment of 100 acres at 30 acres per day, and a 3-man mixing and loading crew.

Hand-Carried Boom

A hand-carried boom outfitted with several spray nozzles (fig. 5) has been used on experimental plots but is not yet recommended for regular project work. However, this method has a potential for special areas, such as along roads where the banks may be too steep for tractor work, or on other small areas where broadcast spraying would be effective but the use of tractor or aerial equipment would be impractical.

A power spray unit, similar to the one used for individual plant spraying, supplies chemical. A high pressure hose connects it to the spray boom. Hose handling, unfortunately, is a major limiting factor both in the ease of operation and in the distance that the boom can be worked from the spray unit. It is not practical to handle more than 200 or 300 feet of hose. Although using this method is strenuous work, it has the advantage of being extremely flexible.

Chemical rate and volume are the same as that used for tractor broadcast spraying. But the progress of spraying will be slower--only 1 to 2 acres per hour--and a 5-man crew may be required. Total per-acre cost for hand broadcast spraying of 4 pounds a.e. of 2,4-D in 20 gallons of emulsion per acre is estimated to be $15 to $20.

Mist Blower

Mist blowers have had limited and rather unsuccessful use in chemical control of brush regrowth in California. Getting an even coverage with a tractor or tractor-trailer unit has proved difficult. Consequently kills have been spotty and inadequate.

Figure 5.--This hand-carried broadcast spray boom has good potential use on small areas where large mechanized equipment would be impractical.

The apparatus sprays an effective swath of 15 to 60 feet, but some chemical drifts for a much greater distance. Application costs are about the same as for tractor spraying, or perhaps a little less.

A back-pack mist blower for broadcast spraying is being tried in several places. It shows good promise for small areas, but more testing is needed before its effectiveness can be determined.

Aerial Broadcast Spraying

The development of low volatile chemical formulations and better spray equipment has materially increased the effectiveness of aerial spraying. It is now the accepted method of application on areas inaccessible to ground equipment.

Aerial spraying on fuel-breaks is done by helicopter since the steep, rough terrain and irregular shaped spray areas just about prohibit the use of fixed-wing aircraft. The helicopter normally used carries 50 to 60 gallons of spray (fig. 6). Under favorable working conditions 50 to 60 acres per hour can be treated when applying a volume of 10 gallons per acre.

Figure 6.-- Helicopter spraying is the only feasible method of application on steep, inaccessible terrain. This model carries a 60-gallon load and sprays an effective swath about 40 feet wide.

Our recommended rate and volume is 6 pounds a.e. of active chemical in 20 gallons of emulsion per acre. A spray mixture consists of $1\frac{1}{2}$ gallons of 2,4-D (or 50-50 D and T when treating hard-to-kill plants), 1 gallon of diesel oil, and $17\frac{1}{2}$ gallons of water. We recommend spraying each area twice, applying two 10-gallon amounts each time for a total of 20 gallons of emulsion per acre. This double-flying increases the application cost $2 to $3 per acre, but assures better spray coverage, especially on steep terrain. Skips and inadequate volumes were often a shortcoming of some of the early aerial spray work.

Double-flying may not be necessary on flat terrain when flagmen are used, and lower volumes should give satisfactory results for plants with open crowns. For example, a volume of 10 g.p.a. should be adequate on small, open, chamise plants.

Adverse weather seriously limits the use of aerial spraying. Flying is generally restricted to a few calm hours in the early morning. Spray operations should stop when wind exceeds 5 miles per hour. Since the helicopter usually flies 20 to 25 feet, or higher, above the ground, even a slight amount of wind will cause some spray drift. This problem can be reduced somewhat with the use of viscous, invert spray emulsions (2, 8). Plant kill seems to be comparable to that obtained with regular herbicide emulsions (8, 15). However, since application cost may be much higher and special equipment may be required, this method may have limited use on fuel-breaks.

Aerial application is generally more expensive than tractor spraying. For example, the initial application of a standard mixture of 6 pounds a.e. of 2,4-D in 20 gallons of emulsion per acre, double-flying on 100 acres, should cost about $15 per acre. Follow-up spraying will cost about the same.

Individual Plant Spraying

Spraying individual plants is a high-volume treatment. All the leaves and stems of each plant are thoroughly drenched to the point of runoff. Complete coverage is essential for best results. Volumes range from 50 to 250 gallons per acre, depending on the number of plants and the size and density of the regrowth. For example, a stand of 3,000 plants per acre with sprouts 12 to 16 inches tall would require about 150 to 200 gallons of spray emulsion.

Close supervision of the spray crew is necessary to insure a thorough job. Thorough coverage is one of the required ingredients of successful plant kill with all types of application. Half-sprayed plants will usually survive. But even with the best surveillance, some plants will usually be missed and seedlings are easily overlooked.

Where used.--Individual plant treatment has a definite place in brush control work:

a. for both initial and follow-up control of resistant species. It is the best way of obtaining complete root kill. Two or three annual treatments may be required to kill all plants.

b. on areas with low plant density--less than 100 to 200 per acre.

c. on areas where broadcast methods cannot be used because of either physical obstructions or drift hazard.

When used.--Individual plant treatment is recommended primarily in the spring, during the latter part of the active growth period. However, work to date indicates that satisfactory control can be obtained at any season if the plants are thoroughly sprayed. Best results are obtained on young sprouts, but treatment should not begin until all of the sprouts have emerged.

Several types of equipment are available for spraying individual plants, but most of them fall into two broad groups--power sprayers and back-pack sprayers.

Power Sprayers

Power sprayers are mounted on tractors, trucks, or trailers (fig. 7). Basically they all consist of a power unit, pump, and supply tank. Agitation of chemical by recirculation or by mechanical means insures a uniform spray mix and prevents settling out of the chemical. Chemical is supplied to a hand wand through a small, high pressure hose connected to the spray unit. Most power sprayers will handle 2 to 4 wands.

This type of equipment is especially good on large, fairly dense plants where high volume and pressure are necessary to obtain good coverage. However, the area must be accessible to ground equipment, and handling hose can be a problem if the area is not cleared of snags. If snags are present, the job moves along at a slow pace, and extra manpower is required to keep the hose untangled. Spraying at distances greater than 300 feet from the power sprayer is not recommended.

Where regrowth is small and snags have been removed, each spray man should spray $\frac{1}{2}$ to $1\frac{1}{2}$ acres a day in a stand of 1,500 or so plants per acre. If the plants are large and snags are present, production may drop to less than $\frac{1}{2}$ acre per day. Acreage covered normally increases with a decrease in plant numbers. If only a few plants are present, say 40 to 50 per acre, a back-pack sprayer might be more practical.

The standard formulation is 4 pounds a.e. of brushkiller (2,4-D and 2,4,5-T) in 98 gallons of water and 1 gallon of diesel oil. The 2,4-D alone is recommended for easy-to-kill plants.

Figure 7.--Power spray equipment comes in many shapes and sizes. This 250-gallon trailer unit normally supplies chemical for two spray wands.

The cost of individual treatment is extremely variable, and at best is usually more expensive than any kind of broadcast spraying. Spray projects of different sizes and under various conditions have cost about $45 per acre and up in the last 5 years. The estimated cost of initial spraying, with a standard rate of brushkiller, in a stand of 14-inch plants which average about 1,500 individuals per acre is $65. This estimate assumes that chemical is applied from a spray trailer which is already on hand and that the area is readily accessible by vehicle. It also assumes a 5-man spray crew, treating 2 acres per day.

The cost of follow-up treatment will depend on the success of the initial spray job. If the first one kills half the plants, retreatment should cost at least a third less than the initial spray--other conditions remaining equal. However, if poor kill is obtained and substantial regrowth develops, the first follow-up treatment may cost about the same as the initial spray job.

A second follow-up treatment, if needed, should cost considerably less than the initial treatment. It may amount to spraying 50 to 100 fairly small plants per acre. This should require about 10 to 20 gallons of spray mix per acre. About 5 to 6 acres can be treated per man-day.

Back Pump Sprayers

Back-pack sprayers come in a variety of shapes and sizes. They usually have a metal container with a capacity of 2 to 5 gallons (fig. 8). They have a trombone- or lever-operated pump (fig. 8), or may be operated by compressed air (fig. 9). A 4-gallon, firefighter's back-pump unit fitted with the proper spray nozzle makes a sturdy, but rather heavy backpack. Recent development of a light weight, chemical resistant, neoprene or plastic container should increase the popularity of back-pump spraying (fig. 10).

Spray procedure is about the same as with power equipment; that is, the leaves and stems are thoroughly drenched with chemical. But the work may go more slowly. Back-pumps use relatively low pressures. They must be filled frequently and may require an extra man to keep the sprayer supplied with chemical. On the other hand, hose handling is not a problem, and work is not restricted to an area a short distance from the spray supply. This is an excellent method of treating occasional plants that survive broadcast treatment.

The concentration of chemical in the spray mixture should be increased for back-pump spraying to compensate for the lower volume that is usually applied. A mixture of 8 pounds a.e. of chemical in 97 gallons of water and 1 gallon of diesel oil is recommended.

The cost of a back-pump spray operation is extremely variable, depending to a large degree on distance between the chemical supply and the work area, and on the number and crown density of the plants being sprayed. Each man may treat 1/3 to 1 acre a day in an open stand of

← Figure 8.--This metal back-pump has a 5-gallon capacity and is operated with a trombone type pump. It is sturdy but heavy and therefore hard to carry.

↑

Figure 9.--Sprayers can be operated by compressed air. This 3-gallon unit must be pumped up every 10 to 15 minutes.

← Figure 10.--Light-weight back-pump sprayers like this chemical-resistant fabric bag should increase the popularity of this type of spraying. The bag is durable and formfitting.

fairly small plants. Total per-acre spray cost will exceed that of a power spray operation when treating an area with a large number of plants. And cost will increase substantially as the distance from the supply source increases, because a considerable number of man-hours are spent in carrying chemical to the spray men.

Assuming 1,500 fourteen-inch plants per acre, the cost for a back-pump operation will be about $80 per acre. Labor cost is the major increase; it doubles if production is cut to $1\frac{1}{2}$ acres per day for a 5-man crew.

Back-Pack Mist Blowers

Portable back-pack mist blowers have been gaining popularity in recent years (fig. 11). Several makes and models are on the market. They all operate essentially the same way as the large tractor-trailer mounted units and have the desirable characteristic of applying a very low, but effective volume of chemical at high velocity. Supplying the blower is less of a problem than with other back-pump sprayers, and the high velocity helps the spray penetrate dense plants. Spray production is estimated to be about 1/2 to $1\frac{1}{2}$ acres per man day. More field experience is needed before definite production figures can be given.

Weight of mist blowers limits their use. Most units weigh 45 to 55 pounds when loaded. Carrying a load of this size is practically impossible on some of the terrain that must be treated, both physically and from the standpoint of personnel safety.

A concentrated chemical emulsion is recommended for mist spraying: 1 gallon (4 pounds a.e.) of active herbicide, 1 gallon of diesel oil, and 3 gallons of water. An accurate record of the amount of spray volume needed per acre for individual plant treatment is not available. However, an estimate of 10 to 12 gallons per acre is made.

The estimated cost of a spray operation for 14-inch plants averaging 1,500 individuals per acre, is $36. This estimate assumes that two back-pack mist blowers are already on hand (the cost of a sprayer varies with size, from $200 to $350) and a 4-man spray crew who treat 4 acres per day.

SOIL TREATMENT

Some herbicides can be applied to the soil and subsequently enter the plant through its roots (7). Although this method of application has been used on agricultural land for several years, it has not been very successful in wildland areas. Attempts with powder or granular applications of 2,4-D and other phenoxy herbicides generally have been unsatisfactory (15). More effective chemicals are being tested, and although results are still not clear-cut enough to warrant specific control recommendations, soil treatment has certain advantages and deserves some discussion.
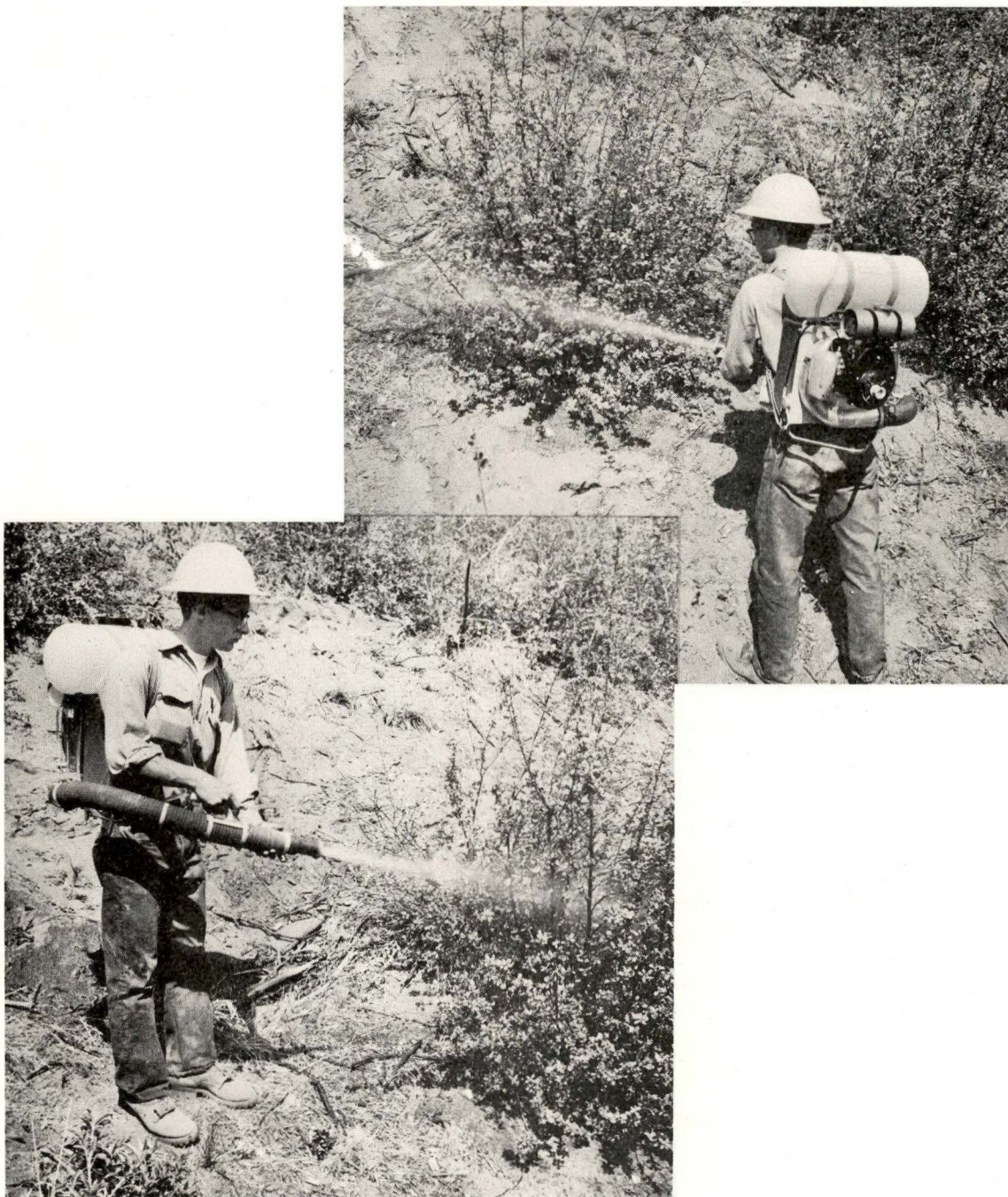
Figure 11.--This mist blower weighs about 45 pounds when loaded with 2-1/2 gallons of herbicide mix. It blasts out a chemical mist at high velocity giving good penetration of dense sprout clumps.

Chemicals.--Fenuron (3-phenyl-1, 1-dimethylurea) is a promising material. Closely related to certain soil sterilants, it is more soluble and hence is readily leached down into the root zone of woody plants. It is a white, crystalline solid commonly formulated in granules containing 25 percent active ingredients (fig. 12). It is nonvolatile and noncorrosive.

Where used.--Fenuron might be used to control either plants that have started sprouting or those that have just been cut--if the date of the clearing operation corresponds to a favorable date of application. This procedure has the advantage of combining the clearing and the control operations. If control is successful, sprout growth should be prevented. Fenuron must be used with caution when applied near desirable trees. If their roots enter the treatment area they may be injured.

When used.--Fenuron is applied in the fall or winter depending on the amount of rainfall that is expected. An irrigation study indicated that there should be at least 3 to 5 inches of moisture to satisfactorily move the chemical downward (17). Field work in southern California indicates that several times this amount of rainfall may be necessary. The amount needed will depend a good deal on the soil texture; less moisture is required on coarse soils than on heavy soils.

Since Fenuron is available in the soil to a plant for a considerable length of time, the date of application is far less critical than for other methods of control. Duration in the soil is dependent on such factors as soil texture, percent of organic matter, amount of precipitation, and rate of application. But the material should remain active for 3 to 12 months (11).

How applied.--Fenuron can be applied broadcast or to individual plants. Most of the initial work with this chemical consisted of broadcast applications (7). This is economically feasible on areas of susceptible plants where low chemical rates--8 to 10 pounds per acre--are effective. On hard-to-kill plants, generally the same species that are hard to control with 2,4-D, only high rates show promise of success. Results have been too erratic to recommend specific chemical rates, and none seem economically feasible for resistant species.

Individual plant treatment offers a greater potential. A fairly high rate can be administered as required to the tough species and lower rates on the susceptible plants. The herbicide is put where it will do the most good--right around the plant to be controlled. One to two ounces may be needed for some plants, but more testing is needed before specific rates can be recommended.

The cost of treatment will depend on rate and method of application. Assuming that chemical costs $1.15 per pound and a rate of one ounce per plant is used, chemical (for a stand of 1,000 plants per acre) will cost $72. Labor, equipment mileage, etc. will run from $10 to $15 per acre.

Figure 12.--Herbicides can be applied to the soil around the base
of undesirable plants. Often the chemical is in the form of small
pellets which dissolve, and the chemical leaches into the soil
where it is picked up by the plant roots.

Total cost per acre will be about $85. This is a high cost, but if the method succeeds, follow-up applications which are usually needed with other methods will not be required.

CUT-STUMP TREATMENT

Control of regrowth on hand-cleared areas may be obtained by applying herbicide on the stumps at the time of cutting. This method has been successful on certain plant species in northern California and elsewhere (10). However, it has had limited use in southern California on chaparral plants. One research test and one or two trial projects are the only use we know of. Results have been erratic and generally unsatisfactory. On the test area, treatment reduced regrowth on most of the treated plants but killed few plants. Final results are not yet available. They may indicate that this method will have only limited use for special plant control problems. Stump treatment in conjunction with follow-up foliage applications may provide more effective control than foliage application alone, but this procedure needs to be tested.

Chemical formulations and methods of application.--Stumps can be treated in several ways with many different herbicides. Three combinations which are considered good choices are:

a. the undiluted amine form of 2,4-D generously painted on the fresh cut surface of the stump (fig. 13).

b. a 50-50 brushkiller mixture of low volatile esters of 2,4-D and 2,4,5-T at a rate of 16 pounds a.e. in 96 gallons of diesel oil. The mixture is thoroughly sprayed over the cut surface and sides of the stump down to ground level (fig. 14).

c. ammate at 4 pounds per gallon of water plus a spreader-sticker agent. The mixture is painted or sprayed on the cut surface alone or over the entire top and sides. The manufacturer also suggests sprinkling ammate crystals on the cut surface.

Where used.-- Stump applications are limited to areas that are hand cleared. Preferably the plants should have only one or two well defined stems. Several chaparral species often produce many small stems from a single plant. Treating all of the stems is too time consuming and misses are too probable for cut stump treatment to be practical (10).

When used.--The time of year for application has not been identified. Successful control has been reported at all seasons (9), but most workers report best results in winter or spring (13). How significant the date of application is will have to be determined. Clearing operations are usually done throughout the year, but it may prove necessary to limit stump application to certain seasons.

Figure 13.--Straight 2,4-D amine painted on the surface of a freshly cut stump gives good control of some plant species. However, effective use of this method on chaparral plants has not yet been demonstrated.
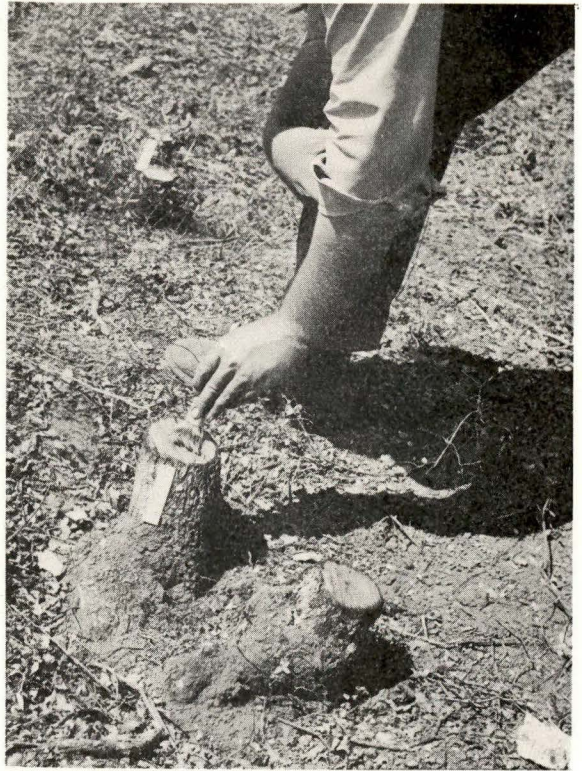
Figure 14.--Freshly cut stumps can be treated with a brushkiller mixture of 2,4-D and 2,4,5-T in diesel oil or ammate in water to prevent subsequent resprouting.

Cost of application.--To paint 2,4-D amine on the cut surface of stumps will cost an estimated $35 to $40 per 1,000 plants having an average of three 3-inch stems per plant. This estimate assumes that 1/2 ounce of chemical per plant, or about 3-1/3 gallons per 1,000 plants, are required.

To spray entire stumps in the same stand of 1,000 plants with brushkiller will cost $65 to $70, assuming that 1 gallon of spray mix will treat 10 plants, or 100 gallons for the 1,000 plants.

Ammate costs about $0.20 per pound, or $0.80 per gallon of mix. If the chemical is painted on the cut surface only, the cost will be about $26 for 1,000 plants. If the chemical is sprayed over the entire stump, the costs may be as high as $100 to $110 per 1,000 plants.

Use of the cut stump method to control chaparral species is not yet recommended. More research is needed to determine where it can be used effectively. In general, easy-to-kill plants like chamise and sage can probably be controlled at less expense with broadcast foliage spraying.

HAZARDS AND PRECAUTIONS

The use of herbicides, particularly broadcast applications of 2,4-D and similar phenoxy chemicals, places a definite responsibility on the spray operator to observe certain precautions and to maintain close control over the entire operation. Care to observe recommended use and procedures is essential to:

...avoid damage to desirable plants
...achieve maximum effectiveness
...work safely.

Special consideration should be given to the following points:

Chemical drift.--Herbicides by their nature are a potential hazard to desirable plants on or near the treated area. Foliage application, in particular, produces highly atomized particles of chemical which can drift for hundreds of feet.

Aerial broadcast spraying requires special precautions since chemical is released several feet above the ground and hence has considerable opportunity to drift outside the treatment area. Aerial spraying should definitely not be done when wind exceeds 5 miles per hour.

Wind effect is not quite as critical with tractor broadcast spraying; wind gusts up to 10 m.p.h. can be tolerated if no susceptible plants are nearby.

Even drift from hand spraying can be a problem if susceptible plants are near. In such conditions, no type of foliage application may be safe.

The drift hazard becomes more critical as operations approach developed areas. A use permit must be obtained from the County Agricultural Commissioner before 2,4,5-T and 2,4-D can be used on State and private land. It has been standard procedure to obtain a permit for similar spray work on National Forest land. Such a requirement is highly desirable since it gives a qualified authority the opportunity to evaluate the potential hazard of each job.

Contaminated equipment.--Equipment used for spraying 2,4-D and 2,4,5-T should be thoroughly cleaned when the spray job is completed. Although these chemicals do not corrode metal, they damage desirable vegetation if contaminated equipment is used for other types of spraying at a later date. Using special equipment solely for herbicide work is a good policy.

Ammate, unlike 2,4-D, is extremely corrosive. Equipment must be thoroughly cleaned after each day's use.

Proper clothing.--Special clothing is not required for normal use of 2,4-D and 2,4,5-T. So far, these chemicals have not proved hazardous to spray crews. However, concentrated chemical on the skin is certainly to be avoided; cleaning material should be available should this occur.

One hazard that does exist is the danger caused by flammability of work clothes worn for spraying, especially when diesel oil is added to the spray mix. Since fire crews are often used on spray projects, they should have a change of clothes available to wear for fire duty.

Close supervision.--Close supervision is an essential aspect of any spray job. It is a necessary requirement to insure that the job is done safely and thoroughly. Many spray jobs have had poor results because of sloppy, careless work. Since spraying is often extremely tedious, bad habits easily develop. However, poor results stemming from poor supervision are difficult to justify.

Read the label.--The herbicide manufacturer is required to indicate on the container label the registered uses for his product. Other precautions and recommended spray procedures are usually given. Toxic chemicals and their concentrations are also identified. The label should always be carefully checked to make certain that the desired chemical formulations and concentrations are used.

HOW TO MIX EMULSIONS

A properly mixed emulsion is essential for effective herbicide spraying. Difficulty in obtaining a good water-oil emulsion can be avoided if the crew is instructed to follow this procedure:

1. Determine the chemical rate and the volume of emulsion that is required for the immediate job.

2. Determine the amount of chemical, diesel oil, and water needed (tables 8 and 9, appendix).

3. Check the label on the chemical container to determine the number of pounds acid equivalent per gallon of formulation. Most formulations contain 4 pounds a.e. per gallon, which equals 1 pound per quart (tables 8 and 9 are set up on this basis). If the formulation contains more or less than 4 pounds per gallon, adjust the measurement accordingly.

4. Then:

First--add the chemical to the diesel oil and mix thoroughly.
Second--add the chemical-diesel oil mixture to the water while it is being thoroughly agitated mechanically, by recirculation through the system, or both.
Third--always keep the emulsion well agitated during the spraying operation.

Spray emulsion should be mixed for only one day's operation. It may be stored for a few days if necessary, but then it should be thoroughly agitated for at least 5 to 10 minutes before being used.

RECOMMENDATIONS FOR FIELD USE

The following brush control recommendations are based on two assumptions: (a) that complete plant kill is desired, and (b) that brush regrowth, 1 or 2 years old, is to be treated. Older growth should be removed and herbicides then used to control new growth that develops.

Foliage applications of 2,4-D and 2,4,5-T are recommended. Other herbicides and methods of application discussed are not recommended at this time. Changes will be made as new information becomes available.

Broadcast spraying is done during the later part of the spring growing season, before the leaves harden. The date will vary, depending on growing conditions and on location. In a year of normal rainfall and average temperature, spray first-year sprouts in May and second-year sprouts from mid-April to mid-May. Under unfavorable growing conditions, when sprout and seedling development is slow, spraying may be delayed 2 to 3 weeks. Elevation also affects sprout development. Plants at higher elevations may be ready for spraying a week or two later than those at low elevations. In general, sprouts should normally be 1 to 2 feet tall.

Individual plant spraying, although best during the spring growing season, is effective at any season.

Brush types are classified in two groups as to ease of kill:

Chamise-chaparral and sage types.--These types are dominated by sensitive species which can usually be killed with broadcast spraying. Satisfactory control may require two applications; consequently the spray program should be planned for two consecutive years. Plants which survive broadcast treatment will require individual plant treatment the next year.

Mixed chaparral and oak types.--These types include resistant species which usually require repeated saturation spraying of individual plants for complete root kill. Two or three consecutive annual applications are sufficient to kill most plants. Broadcast spraying is usually recommended for the initial treatment, especially when susceptible plants and seedlings are present.

Specific spray recommendations for these two types are as follows:

Chamise-Chaparral and Sage Types
(Susceptible Species)

A. INITIAL SPRAYING

1. Tractor Broadcast Spraying is recommended on favorable terrain.
    a. Plants with dense crowns - use----
        1 gal (4 lb a.e.) 2,4-D
        1 gal diesel oil
        18 gal water
        ――――――
        20 gpa

    b. Small plants, open crowns - use--
        1 gal (4 lb a.e.) 2,4-D
        3/4 gal diesel oil
        13-1/4 gal water
        ――――――
        15 gpa

2. Helicopter Broadcast Spraying is recommended on inaccessible terrain.
    a. Plants with dense crowns
        (1) Flat terrain - use----
             1-1/2 gal (6 lb a.e.) 2,4-D
             3/4 gal diesel oil
             12-3/4 gal water
             ――――――
             15 gpa

        (2) Steep terrain - use----
             1-1/2 gal (6 lb a.e.) 2,4-D
             1 gal diesel oil
             17-1/2 gal water
             ――――――
        (Apply in two 10-gallon amounts)   20 gpa

    b. Small plants, open crowns
        (1) Flat terrain - use----
             1 gal (4 lb a.e.) 2,4-D
             1/2 gal diesel oil
             8-1/2 gal water
             ――――――
             10 gpa

    (2) Steep terrain - use---- 1-1/2 gal (6 lb a.e.) 2,4-D
                   3/4 gal diesel oil
                 12-3/4 gal water
(Apply in two 7½ gallon amounts) 15 gpa

3. Individual Plant Spraying is recommended where other methods are not feasible.

          use----   1 gal (4 lb a.e.) 2,4-D
                1 gal diesel oil
               98 gal water
              100 gal

B. FIRST FOLLOW-UP SPRAYING

1. Poor Plant Kill from initial spraying - repeat ----A-1, 2, or 3

2. Good Plant Kill from initial spraying - use

                1/2 gal (2 lb a.e.) 2,4-D
     individual plant spraying---- 1/2 gal (2 lb a.e.) 2,4,5-T
                1 gal diesel oil
               98 gal water
              100 gal

C. SECOND FOLLOW-UP SPRAYING

For surviving plants use treatment ----   B-2

Mixed-Chaparral and Oak Types
(Resistant Species)

A. INITIAL SPRAYING

1. Tractor Broadcast Spraying is recommended on favorable terrain.

         use----   1/2 gal (2 lb a.e.) 2,4-D
                1/2 gal (2 lb. a.e.) 2,4,5-T
               1 gal diesel oil
              18 gal water
              20 gpa

2. Helicopter Broadcast Spraying is recommended on inaccessible terrain.

  a. Flat terrain - use---- 1/2 gal (2 lb a.e.) 2,4-D
                1/2 gal (2 lb a.e.) 2,4,5-T
               3/4 gal diesel oil
             13-1/4 gal water
              15 gpa

  b. Steep terrain - use---- 3/4 gal (3 lb a.e.) 2,4-D
                3/4 gal (3 lb a.e.) 2,4,5-T
               1 gal diesel oil
             17-1/2 gal water
(Apply two 10-gallon amounts) 20 gpa

3. <u>Individual Plant Spraying</u> is recommended where other methods are not feasible. -   use----   1/2 gal (2 lb a.e.) 2,4-D
                                                           1/2 gal (2 lb a.e.) 2,4,5-T
                                                               1 gal diesel oil
                                                                   <u>98</u> gal water
                                                               100 gal

B.   FIRST FOLLOW-UP SPRAYING

    1.   <u>Poor Plant Kill</u> of susceptible plant species with the initial spraying - repeat ----A-1, 2, or 3.

    2.   <u>Good Plant Kill</u> of susceptible plant species from the initial spraying - repeat ----A-3.

C.   SECOND FOLLOW-UP SPRAYING

    For surviving plants repeat ----A-3.

D.   THIRD FOLLOW-UP SPRAYING

    For surviving plants repeat ----A-3.

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APPENDIX

Table 1.--Susceptibility of 1- to 2-year-old regrowth of southern California woody plants to foliage treatments of 2,4-D and 2,4,5-T

Plant names		Resistance to control[1]	Remarks
Common	Scientific		
Baccharis, spp.	Baccharis spp.	Susceptible	--
Broom, Scotch	Cytisus scoparious	Susceptible	--
Flattop eriogonum	Eriogonum fasciculatum	Susceptible	--
Ceanothus spp.	Ceanothus spp.	Intermediate	--
Ceanothus, hoaryleaf	Ceanothus crassifolius	--	Non-sprouter
Chamise	Adenostoma fasciculatum	Susceptible	--
Chaparral pea	Pickeringia montana	Resistant	--
Cherry spp.	Prunus spp.	Resistant	--
Currants, spp.	Ribes spp.	Intermediate	--
Broom deervetch	Lotus scoparius	Susceptible	--
Elderberry	Sambucus spp.	Intermediate	--
Calif. Laurel	Umbellularia californica	Resistant	--
Manzanita spp.	Arctostaphylos spp.	Intermediate	Variable
Manzanita, bigberry	Arctostaphylos glauca	--	Non-sprouter
Maple, bigleaf	Acer macrophyllum	Resistant	--
Birchleaf mahogany	Cercocarpus betuloides	Intermediate	--
Mountain misery	Chamaebatia foliolosa	Intermediate	--
Oak, live	Quercus spp.	Resistant	--
Oak, poison	Rhus diversiloba	Resistant	--
Redshank	Adenostoma sparsifolium	Intermediate	Variable
Buckthorn spp.	Rhamnus spp.	Resistant	--
Sage spp.	Salvia spp.	Susceptible	--
Sagebrush	Artemisia spp.	Susceptible	--
Tamarisk	Tamarix spp.	Intermediate	--
Silktassel	Garrya veatchii	Intermediate	--
Sumac spp.	Rhus spp.	Resistant	--
Sycamore, California	Platanus racemosa	Resistant	--
Toyon	Heteromeles arbutifolia	Intermediate	--
Yerba santa spp.	Eriodictyon spp.	Intermediate	Variable

[1] Intermediate and resistant species will receive same control treatment; important species which are non-sprouting are noted in the remarks column.

Susceptible.--95 percent or more of all plants will usually be completely root-killed with one or two successive broadcast spray applications--each containing at least 4 lb a.e. of brushkiller per acre.

Intermediate.--30-70 percent of the plants may be completely root-killed with one or two broadcast spray applications--each containing at least 4 lb. a.e. of brushkiller per acre. Follow-up, individual plant spraying will be needed to finish off surviving plants.

Table 1.--Footnotes continued

Resistant.--Less than 30 percent of the plants usually will be root-killed with two broadcast spray applications--each containing at least 4 lb a.e. of brushkiller per acre. One or two follow-up, individual plant sprayings will always be required to completely kill the surviving plants.

Note: 1- or 2-year-old seedlings of all brush species are usually very susceptible to broadcast spraying of brushkiller applied at the proper time in the spring.

Table 2.--Approximate spacing between plants and the numbers of plants in a small sample areas for different numbers of plants per acre

Approx. spacing (ft.)	No. of plants per acre	No. of plants per sample circle of size--		
		0.1 acre (radius 37.23 ft.)	0.01 acre (radius 11.77 ft.)	0.001 acre (radius 3.75 ft.)
	1	--	--	--
66 x 66	10	1	--	--
	20	2	--	--
	30	3	--	--
30 x 30	40	4	--	--
	50	5	--	--
	60	6	--	--
25 x 25	70	7	--	--
	80	8	--	--
	90	9	--	--
20 x 20	100	10	1	--
14 x 14	200	20	2	--
12 x 12	300	30	3	--
10 x 10	400	40	4	--
9 x 9	500	50	5	--
8 x 8	600	60	6	--
	700	70	7	--
	800	80	8	--
7 x 7	900	90	9	--
6 x 6	1,000	100	10	1
5 x 5	2,000	200	20	2
4 x 4	3,000	300	30	3
	4,000	400	40	4
3 x 3	5,000	500	50	5
2 x 2	10,000	1,000	100	10

Table 3.--Area in acres of different sized swaths 1 mile long

Swath width, (ft.)	Acres per mile			Swath width, (ft.)	Acres per mile
1.0	0.1212			5.5	0.666
1.5	.1818			6.0	.7272
2.0	.2424			6.5	.7878
2.5	.3030			7.0	.8484
3.0	.3636			7.5	.9090
3.5	.4242			8.0	.9696
4.0	.4848			8.5	1.0303
4.5	.5454			9.0	1.0909
5.0	.6060			9.5	1.1515

Area in acres for any swath width may be determined by:

a. Formula--acres/mile = (W) (0.1212); W = width in feet

For example, a swath 92 feet wide and 1 mile long contains how many acres?

92 feet x 0.1212 = 11.153 acres per mile.

b. Adding components of the above table with the decimal point adjusted.

For example, a 92 foot swath contains how many acres?

```
         90 ft. = 10.9090
    +     2 ft. =    .2424
  Total  92 ft. = 11,1514 acres per mile
```

For conversion to hectares, multiply acres x 0.40469.

Table 4.--Distance traveled per 30 seconds, and seconds per 100 feet of
travel, for different speeds in miles per hour

Miles per hour	Feet per 30 sec.	Seconds per 100 ft.	Miles per hour	Feet per 30 sec.	Seconds per 100 ft.
0.1	4	682	2.1	92	33
.2	9	340	2.2	97	32
.3	13	227	2.3	101	30
.4	18	170	2.4	106	28
.5	22	136	2.5	110	27
.6	26	114	2.6	114	26
.7	31	98	2.7	119	25
.8	35	85	2.8	123	24
.9	40	76	2.9	128	24
1.0	44	68	3.0	132	23
1.1	48	62	3.1	136	22
1.2	53	57	3.2	141	21
1.3	57	52	3.3	145	21
1.4	62	49	3.4	150	20
1.5	66	45	3.5	154	19
1.6	70	43	3.6	158	19
1.7	75	40	3.7	163	19
1.8	79	38	3.8	167	18
1.9	84	36	3.9	172	17
2.0	88	34	4.0	176	17

Purpose of Table 4 - to calibrate "rate of travel" which is necessary for:

1. Determining output of a spray boom.
2. Applying a given amount of material per acre--as given in Table 6.

Example: A tractor which goes a distance of 40 feet in 30 seconds is travel-
ing at a speed of 0.9 m.p.h. And a tractor which takes 76 seconds
to move a measured distance of 100 feet is also traveling at a speed
of 0.9 m.p.h.

Formula for the conversion of miles per hour to feet per second:
M.P.H. x 1.4667 = ft. per sec.

Example: A helicopter flying at 20 m.p.h. goes how many feet per second?
20 x 1.4667 = 29.34 ft. per sec.

Table 5.--Nozzle discharge rates in gallons, quarts, and ounces per minute and the time in minutes to discharge 1 quart at these rates

Gallons per minute	Quarts per minute	Ounces per minute	Time per quart Minutes	Minutes & seconds
0.05	0.20	6.4	5.00	5 min. 00 sec.
.06	.24	7.7	4.17	4 min. 10.0 sec.
.07	.28	9.0	3.57	3 min. 34.3 sec.
.08	.32	10.2	3.13	3 min. 7.5 sec.
.09	.36	11.5	2.78	2 min. 46.7 sec.
.10	.40	12.8	2.50	2 min. 30.0 sec.
.11	.44	14.1	2.27	2 min. 16.3 sec.
.12	.48	15.4	2.08	2 min. 5.0 sec.
.13	.52	16.6	1.92	1 min. 55.4 sec.
.14	.56	17.9	1.79	1 min. 47.2 sec.
.15	.60	19.2	1.67	1 min. 40.0 sec.
.16	.64	20.5	1.56	1 min. 33.7 sec.
.17	.68	21.8	1.47	1 min. 28.3 sec.
.18	.72	23.0	1.39	1 min. 23.3 sec.
.19	.76	24.3	1.32	1 min. 19.0 sec.
.20	.80	25.6	1.25	1 min. 15.0 sec.
.21	.84	26.9	1.19	1 min. 11.4 sec.
.22	.88	28.2	1.14	1 min. 8.2 sec.
.23	.92	29.4	1.09	1 min. 5.2 sec.
.24	.96	30.7	1.04	1 min. 2.5 sec.
.25	1.00	32.0	1.000	1 min. 00.0 sec.
.26	1.04	33.3	.960	0 min. 57.7 sec.
.27	1.08	34.6	.926	0 min. 55.6 sec.
.28	1.12	35.8	.893	0 min. 53.6 sec.
.29	1.16	37.1	.862	0 min. 51.7 sec.
.30	1.20	38.4	.833	0 min. 50.0 sec.
.31	1.24	39.7	.806	0 min. 48.4 sec.
.32	1.28	41.0	.781	0 min. 46.9 sec.
.33	1.32	42.2	.758	0 min. 45.5 sec.
.34	1.36	43.5	.735	0 min. 44.1 sec.
.35	1.40	44.8	.714	0 min. 42.8 sec.
.36	1.44	46.1	.694	0 min. 41.6 sec.
.37	1.48	47.4	.676	0 min. 40.6 sec.
.38	1.52	48.6	.658	0 min. 39.5 sec.
.39	1.56	49.9	.641	0 min. 38.5 sec.
.40	1.60	51.2	.625	0 min. 37.5 sec.
.41	1.64	52.5	.610	0 min. 36.6 sec.
.42	1.68	53.8	.595	0 min. 35.7 sec.
.43	1.72	55.0	.581	0 min. 34.9 sec.
.44	1.76	56.3	.568	0 min. 34.1 sec.
.45	1.80	57.6	.556	0 min. 33.4 sec.
.46	1.84	58.9	.543	0 min. 32.6 sec.
.47	1.88	60.2	.532	0 min. 31.9 sec.
.48	1.92	61.4	.521	0 min. 31.3 sec.
.49	1.96	62.7	.510	0 min. 30.6 sec.

Table 6.--Spacing of nozzles and output per nozzle required for different volumes per acre at different speeds[1]

Speed	Gallons per acre														
	5			7.5			10			15			20		
	Spacing of nozzles (inches)														
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
	Output of each nozzle (gals./min.)														
.6	--	--	--	--	--	--	--	--	--	--	--	.06	--	.06	.08
.8	--	--	--	--	--	--	--	--	.05	--	--	.08	--	.08	.11
1.0	--	--	--	--	--	.05	--	--	.07	--	.08	.10	--	.10	.14
1.2	--	--	--	--	--	.06	--	--	.08	--	.09	.12	.08	.12	.16
1.4	--	--	--	--	--	.07	--	--	.09	--	.11	.14	.09	.14	.19
1.6	--	--	.05	--	--	.08	--	.08	.11	.08	.12	.16	.11	.16	.22
1.8	--	--	.06	--	--	.09	--	.09	.12	.09	.14	.18	.12	.18	.24
2.0	--	--	.07	--	.08	.10	--	.10	.13	.10	.15	.20	.13	.20	.27
2.2	--	--	.07	--	.09	.11	--	.11	.14	.11	.17	.22	.14	.22	.30
2.4	--	--	.08	--	.10	.12	.08	.12	.16	.12	.18	.24	.16	.24	.32
2.6	--	--	.09	--	.10	.13	.09	.13	.17	.13	.20	.26	.17	.26	.35
2.8	--	--	.09	--	.11	.14	.09	.14	.18	.14	.21	.28	.18	.28	.38
3.0	--	.08	.10	.08	.12	.15	.10	.15	.20	.15	.23	.30	.20	.30	.40
3.2	--	.08	.11	.08	.13	.16	.11	.16	.21	.16	.24	.32	.21	.32	.43
3.4	--	.09	.11	.09	.13	.17	.11	.17	.22	.17	.26	.34	.22	.34	.46
3.6	--	.09	.12	.09	.14	.18	.12	.18	.24	.18	.27	.36	.24	.36	.49
3.8	--	.10	.13	.10	.15	.19	.13	.19	.25	.19	.29	.38	.25	.38	.51
4.0	--	.10	.14	.10	.16	.20	.14	.20	.26	.20	.30	.40	.26	.40	.54

[1] Only outputs listed below the upper dashed line and above the lower dashed line are considered practical for normal broadcast spraying on fuel-breaks.

Table 7.--Output in gallons per minute of different sized nozzles at different pressures per square inch[1]

Nozzle size	20 p.s.i.	25 p.s.i.	30 p.s.i.	40 p.s.i.	50 p.s.i.	60 p.s.i.
800067	0.05	0.055	0.06	0.067	0.07	0.08
8001	.07	.08	.09	.10	.11	.12
80015	.11	.12	.13	.15	.17	.18
8002	.14	.16	.17	.20	.23	.25
8003	.21	.24	.26	.30	.34	.37
8004	.28	.32	.35	.40	.45	.49
8006	.42	.47	.52	.60	.67	.73

[1] Copied from Spraying Systems Co. Catalog No. 3, p. 5.

Table 8.--Chemical[1], diesel oil, and water requirements for spray emulsions mixed at 5 chemical concentrations and applied at a standard volume of 10 gallons per acre

Acres to be treated	Diesel oil	Chemical rates per 10 gallons of emulsion									
		1 lb/a.		2 lb/a.		3 lb/a.		4 lb/a.		6 lb/a.	
		Chem.	Water	Chem.	Water	Chem.	Water	Chem.	Water	Chem.	Water
	Qt.	Qt.	Gal.	Qt.	Gal.	Qt.	Gal.	Qt.	Gal.	Qt.	Gal.
0.5	1	0.5	4.6	1	4.5	1.5	4.4	2	4.3	3	4.0
1.0	2	1.0	9.3	2	9.0	3.0	8.8	4	8.5	6	8.0
1.5	3	1.5	13.9	3	13.5	4.5	13.7	6	12.8	9	12.0
2.0	4	2.0	18.5	4	18.0	6.0	17.5	8	17.0	12	16.0
2.5	5	2.5	23.1	5	22.5	7.5	21.9	10	21.3	15	20.0
3.0	6	3.0	27.8	6	27.0	9.0	26.3	12	25.5	18	24.0
3.5	7	3.5	32.4	7	31.5	10.5	30.6	14	29.8	21	28.0
4.0	8	4.0	37.0	8	36.0	12.0	35.0	16	34.0	24	32.0
4.5	9	4.5	41.6	9	40.5	13.5	39.4	18	38.3	27	36.0
5.0	10	5.0	46.3	10	45.0	15.0	43.8	20	42.5	30	40.0
5.5	11	5.5	51.9	11	49.5	16.5	48.1	22	46.8	33	44.0
6.0	12	6.0	55.5	12	54.0	18.0	52.5	24	51.0	36	48.0
6.5	13	6.5	60.1	13	59.5	19.5	56.9	26	55.3	39	52.0
7.0	14	7.0	64.8	14	63.0	21.0	61.3	28	59.5	42	56.0
7.5	15	7.5	69.4	15	67.5	22.5	66.6	30	63.8	45	60.0
8.0	16	8.0	74.0	16	72.0	24.0	70.0	32	68.0	48	64.0
8.5	17	8.5	78.6	17	76.5	25.5	74.4	34	72.3	51	68.0
9.0	18	9.0	83.3	18	81.0	27.0	78.8	36	76.5	54	72.0
9.5	19	9.5	87.9	19	85.5	28.5	83.1	38	80.8	57	76.0
10.0	20	10.0	92.5	20	90.0	30.0	87.5	40	85.0	60	80.0

[1] Assumes that the chemical formulation being used contains 4 lb a.e. of 2,4-D and/or 2,4,5-T per gallon.

Table 9.--Formulas for different volumes of spray mixed at 3 concentrations[1]

Spray volume	Diesel oil	Concentration (chemical rates per 100 gal. of emulsion)					
		4 pounds		5 pounds		6 pounds	
		Chem.	Water	Chem.	Water	Chem.	Water
Gal.	Oz.	Oz.	Qt.	Oz.	Qt.	Oz.	Qt.
1	1.5	1.3	4.0	1.6	4.0	1.9	4.0
2	2.5	2.6	8.0	3.2	8.0	3.8	8.0
3	4.0	3.8	12.0	4.8	11.5	5.8	11.5
4	5.0	5.1	15.5	6.4	15.5	7.7	15.5
5	6.5	6.4	19.5	8.0	19.5	9.6	19.5
Gal.	Cup	Cup	Gal.	Cup	Gal.	Cup	Gal.
10	1.5	1.5	10.0	2.0	10.0	2.5	10.0
15	2.5	2.5	14.5	3.0	14.5	3.5	14.5
20	3.0	3.0	19.5	4.0	19.5	5.0	19.5
25	4.0	4.0	24.5	5.0	24.5	6.0	24.5
30	5.0	5.0	29.5	6.0	29.5	7.0	29.0
35	5.5	5.5	34.5	7.0	34.0	8.5	34.0
40	6.5	6.5	39.0	8.0	39.0	9.5	39.0
45	7.0	7.0	44.0	9.0	44.0	11.0	44.0
50	8.0	8.0	49.0	10.0	49.0	12.0	48.5
55	9.0	9.0	54.0	11.0	54.0	13.0	53.5
60	9.5	9.5	59.0	12.0	58.5	14.5	58.5
65	10.5	10.5	63.5	13.0	63.5	15.5	63.5
70	11.0	11.0	69.0	14.0	68.5	17.0	68.0
75	12.0	12.0	73.5	15.0	73.5	18.0	73.0
80	13.0	13.0	78.5	16.0	78.0	19.0	78.0
85	13.5	13.5	83.5	17.0	83.0	20.5	83.0
90	14.5	14.5	88.0	18.0	88.0	21.5	87.5
95	15.0	15.0	93.0	19.0	93.0	23.0	92.5
100	16.0	16.0	98.0	20.0	98.0	24.0	97.5

[1] Assumes that the chemical formulation being used contains 4 lb a.e. of 2,4-D and/or 2,4,5-T per gallon.

2 cups = 1 pt.   4 cups = 1 qt.   16 cups = 1 gal.

Table 10.--Units of measure

LINEAR MEASURE

1 inch		= 2.54 cm.
12 inches	= 1 foot	= 0.305 m.
3 feet	= 1 yard	= 0.914 m.
16½ feet	= 1 rod	= 5.029 m.
5,280 feet	= 1 mile	= 1,609 m.

SQUARE MEASURE

1 sq. inch		= 6.45 sq. cm.
144 sq. inches	= 1 sq. ft.	= 929 sq. cm.
9 sq. feet	= 1 sq. yd.	= 0.84 sq. m.
43,560 sq. feet	= 1 acre	= 0.40 hectare
640 acres	= 1 sq. mile	= 259 hectare

CUBIC MEASURE

1 cu. inch		= 16.387 cu. cm.
1,728 cu. inch	= 1 cu. ft.	= 0.028 cu. m.
27 cu. feet	= 1 cu. yd.	= 0.764 cu. m.

SURVEYORS MEASURE
(Gunter's chain)

7.92 inches	= 1 link	= 20.12 cm.
100 links or		
66 feet	= 1 chain	= 20.12 m.
80 chains	= 1 mile	= 1,609.3 m.

ANGULAR MEASURE

60 seconds (")	= 1 minute (')
60 minutes	= 1 degree (°)
90 degrees	= 1 quadrant or
	1 right angle
4 quadrants or	
360 degrees	= 1 circle

ENGINEER'S CHAIN

1 foot		= 0.304 m.
100 feet	= 1 chain	= 30.48 m.
52.8 chains	= 1 mile	= 1,609.3 m.

WEIGHT MEASURE
(avoirdupois)

1 dram		= 1.772 grams
16 drams	= 1 ounce	= 28.349 grams
16 ounces	= 1 pound	= 453.59 grams
2,000 lbs.	= 1 ton	= 907.18 grams

SURVEYORS SQUARE MEASURE

10 sq. chain	= 1 acre	= 0.404 hectare
640 acres	= 1 sq. mile or 1 section	= 259 hectare
36 sq. mile	= 1 township	= 9.324 hectare

DRY MEASURE

1 pt.	= 33.60 cu. in. = 0.550 liter
2 pts.	= 1 qt.
	= 67.20 cu. in.
	= 1.101 liter

LIQUID MEASURE

Teaspoons	Tablespoons	Ounces	Cups	Pints	Quarts	Gallons	Milliliters
768	256	128	16	8	4	1.00	3785.3
162	64	32	4	2	1	0.25	946.3
96	32	16	2	1	0.5	.13	473.2
48	16	8	1	0.5	.25	.06	236.6
6	2	1	0.13	.06	.03	--	29.6
3	1	0.5	.06	.03	.01	--	14.8
1	0.33	.17	.02	.01	--	--	4.9

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Table 11.--Advantages and disadvantages of various methods of chemical

control of brush regrowth in southern California

BROAD METHODS OF APPLICATION

Advantages	Disadvantages

Foliage Application

Advantages	Disadvantages
1. Most positive method to date for brush control in southern California.	1. Hazard of chemical drift to adjacent areas.
2. Effective on brush sprouts and seedlings.	2. Effective date of application may be limited.
3. Rate of spray application may be rapid.	3. One or more follow-up applications may be required to kill all plants.
4. Cost and material requirements may be low.	4. Operations may be seriously curtailed by adverse weather conditions.

Soil Treatment

Advantages	Disadvantages
1. Chemical mixing and elaborate application equipment unnecessary.	1. Not yet a proved method of control for chaparral.
2. No drift or volatilization hazard.	2. Requires adequate rainfall--amount not yet determined.
3. Chemical available to the plant for a long time.	3. High material cost.
4. Chemical may be applied at the time of brush removal.	4. Slow rate of application.
	5. Adjacent plants may be affected.

Cut-Stump Treatment

Advantages	Disadvantages
1. Elaborate application equipment may be unnecessary.	1. Not yet proved method of control for chaparral.
2. Little or no drift hazard, depending on herbicide used.	2. Control restricted to hand-cleared areas.
3. Chemical control begins immediately after brush removal.	3. Not practical on sprouts or seedlings or multi-stemmed plants.
	4. Slow rate of application.

Table 11.--Advantages and disadvantages of various methods of chemical

control of brush regrowth in southern California, continued

KINDS OF FOLIAGE APPLICATIONS

Advantages	Disadvantages

Broadcast

Advantages	Disadvantages
1. Rapid coverage--up to 50 acres per hour.	1. Not completely effective on resistant brush species.
2. Low material requirements.	2. Chemical drift a problem.
3. Effective on seedlings and susceptible brush species.	3. Limited effective season of application--spring growing season.
4. Relatively inexpensive--as low as $10 to $15 per acre.	4. Operations restricted by adverse weather conditions--wind, visibility, temperature.

Individual Plant

Advantages	Disadvantages
1. Effective on resistant species.	1. Two or more applications may be needed, to completely kill resistant species.
2. Reasonably effective at any season.	2. Plants, especially seedlings, can be missed.
3. Not seriously restricted by adverse weather conditions.	3. Requires a large volume of material, logistics may be a problem.
4. Chemical applied only to plants requiring treatment.	4. Slow rate of production--cost high.
5. Drift hazard moderate to low.	

Table 11.--**Advantages and disadvantages of various methods of chemical**

control of brush regrowth in southern California, continued

KINDS OF BROADCAST APPLICATION

Advantages	Disadvantages

Tractor

Advantages	Disadvantages
1. Uniform thorough coverage.	1. Use limited by accessibility-- snags and steep or broken terrain.
2. Moderate drift hazard.	
3. Moderately restricted by adverse weather conditions-- wind primarily.	2. Moderately slow rate of production.
4. Low application cost when working conditions favorable.	3. Requires large spray equipment.

Hand

Advantages	Disadvantages
1. High flexibility.	1. Limited distance of operation from the supply source.
2. Low equipment requirements.	
	2. Hose handling a major problem.
	3. High manpower requirements.

Mist Blower

Advantages	Disadvantages
1. Equipment not hampered by unwieldy spray booms.	1. Difficult to obtain good, uniform coverage.
	2. Drift hazard.

Aerial

Advantages	Disadvantages
1. Can be used on areas inaccessible to ground equipment.	1. Operations seriously restricted by adverse weather conditions.
2. Rapid coverage.	2. High drift hazard.
	3. Easy to make skips and misses.